Module 2: Basic Stormwater Principles

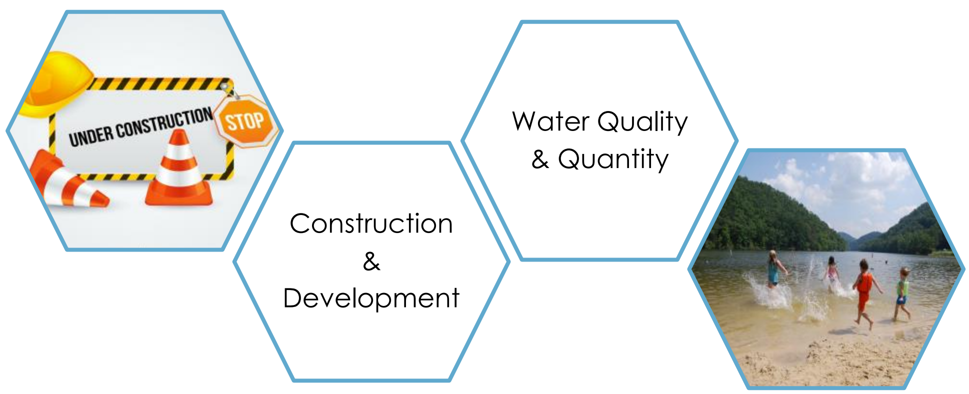
Objectives

- Generalize the goal of the Part II B water quality and quantity technical criteria.
- Explain how runoff characteristics can change as landcover conditions change.

2a. Overview

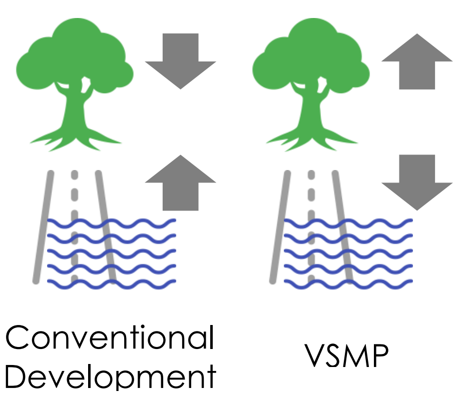
PROGRAM ADMINISTRATORS AND STORMWATER MANAGEMENT

As a program administrator for a VSMP you play a critical environmental role in your community by helping to confirm that construction and development activities follow the requirements of the Virginia Stormwater Management Program (VSMP).



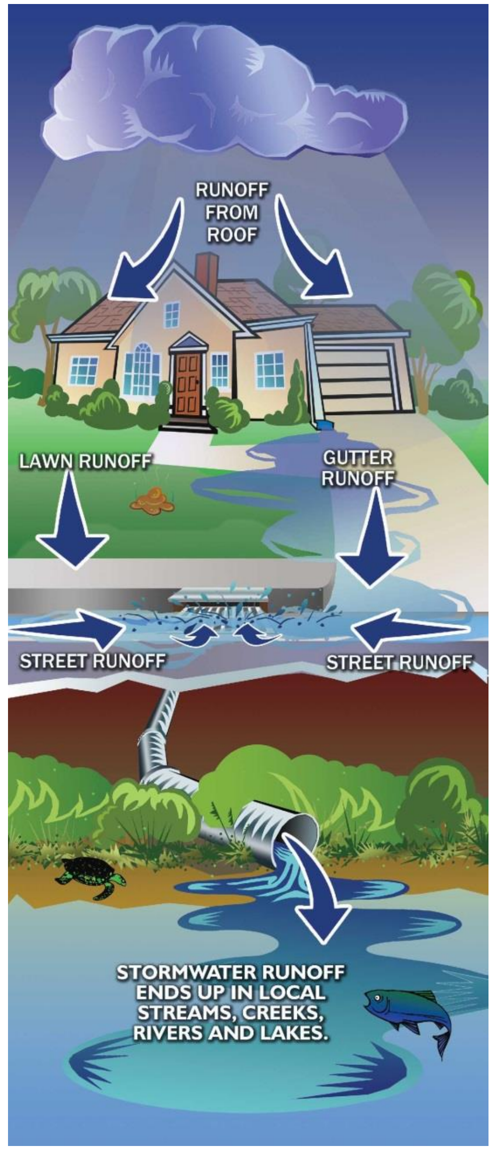
Conventional development has the potential to affect water quality and quantity through changes to a site's landcover. This change of landcover often results in the loss of natural processes and increased stormwater runoff which can have an impact on downstream properties and natural resources. Virginia has adopted a stormwater management approach that encompasses both environmental site design and the use of stormwater best management practices (BMPs) to maintain natural processes and reduce the amount of runoff that will leave a site. These topics are discussed in the following sections.

Understanding the connection between construction and development activities and water quality and quantity will add value to your role as a program administrator as you communicate with individuals in your community about the requirements of the VSMP.



DEFINITION OF STORMWATER RUNOFF

Stormwater runoff occurs when the amount of precipitation exceeds the capacity of the ground to absorb water. Runoff washes off impervious surfaces like compacted soils, roofs, driveways, sidewalks, and roads, and carries sediment, trash, oil, fertilizers, and other pollutants to local waterways.



Courtesy NCDENR

VSMP TECHNICAL CRITERIA

The Virginia Stormwater Management Program includes technical criteria (II B and II C) that must be met in the stormwater management plan to address:

- ***Water quality*** for the protection of state waters from the pollutants that are carried off a developed site in stormwater runoff; and

- ***Water quantity*** for the protection of state waters from channel erosion and flooding that can result from an increase in the volume and flow of stormwater runoff that leaves a developed site.

The II B ***water quality*** technical criteria establish a threshold for total phosphorus that can be allowed to leave a site through stormwater runoff. Phosphorus is both a pollutant associated with land development and a marker that can be targeted for the minimization of other related pollutants. While phosphorus is naturally found in fresh water, even small increases can have adverse effects on water quality and aquatic life.

NOTE:

Compliance with the Part II B water quantity criteria satisfies minimum standard 19 of the Erosion and Sediment Control Regulations.

Virginia Runoff Reduction Method

The Regulations require the use of the Virginia Runoff Reduction Method (or another Board approved method) to evaluate compliance with the Part II B water quality criteria for new development and redevelopment (9VAC25-870-63 A). The advantage of using the Virginia Runoff Reduction Method is that it incorporates the reduction of post-development stormwater runoff through the use of environmental site design and DEQ approved stormwater best management practices (BMPs) which can then also be applied towards compliance with Part II B ***water quantity*** criteria (9VAC25-870-66).

NOTE:

There are two Virginia Runoff Reduction Method spreadsheets that are used to verify compliance with the Part II B water quality criteria - one for new development and one for redevelopment. The redevelopment spreadsheet checks for compliance with the phosphorus threshold by comparing the proposed landcover to the predevelopment landcover.

Predevelopment refers to the conditions that exist at the time that plans for the land development of a tract of land are submitted to the VSMP authority.

Environmental Site Design

Environmental Site Design is the practice of using small-scale stormwater management practices, nonstructural techniques, and better site planning to mimic natural runoff characteristics and minimize the impact of land development on water quality and quantity by reducing the amount of stormwater runoff that will leave a site.

ESD promotes:

- Conserving natural features and resources (e.g., drainage patterns, native soil, native vegetation);
- Minimizing impervious surfaces (e.g., pavement, concrete channels, rooftops);
- Slowing down runoff to maintain discharge timing and to increase infiltration and evapotranspiration on the development site; and
- Using other non-structural practices or innovative technologies approved by DEQ.

Best management practices (BMPs)

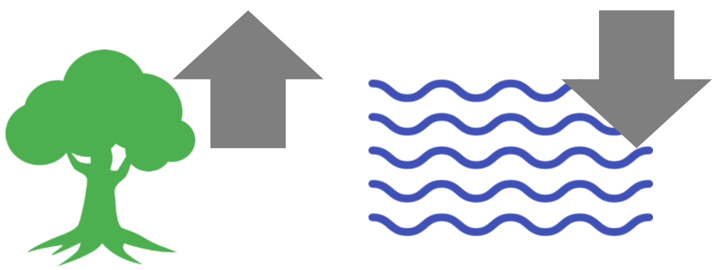
If a site's design does not initially meet the technical criteria, then DEQ approved best management practices (BMPs) must be added to the design to reduce stormwater runoff and/or remove pollutants from stormwater runoff. The 15 non-proprietary BMPs are discussed later in this module.

SUMMARY

Different landcover conditions result in different stormwater runoff characteristics. For example, a forested area will have very little stormwater runoff flow compared to an impervious parking lot.

Therefore, minimizing land cover changes and using Environmental Site Design principles will:

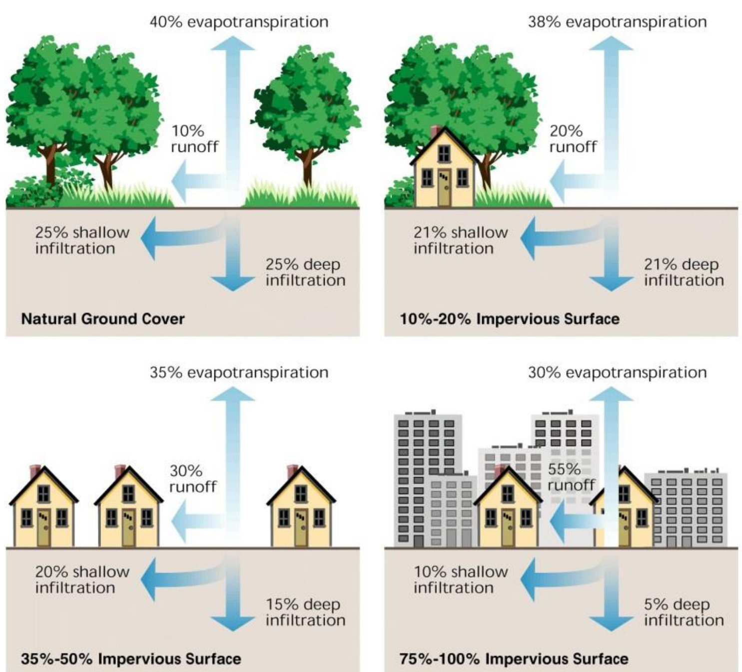
1. Enhance the natural functions of beneficial site resources, and
2. Reduce the amount of runoff that will leave a site, which assists in meeting the Part II B water quality and water quantity criteria.



2b. Effects of Landuse on the Hydrologic Cycle

As population growth increases, the demand for buildings, homes and infrastructure also increases. In the past, development often led to the loss of many important environmental processes including:

- Reduced evapotranspiration, interception, and infiltration from the loss of vegetation;
- Reduced infiltration from the removal of topsoil and compaction of subsoil;
- Reduced groundwater recharge and stream base flows from increased stormwater runoff over impervious surfaces;
- Reduced infiltration from the use of built drainage systems such as gutters, storm sewers and smooth-lined channels; and
- Declining watershed health from increased imperviousness.



Relationship between impervious cover and runoff
Federal Interagency SWRG, 1998

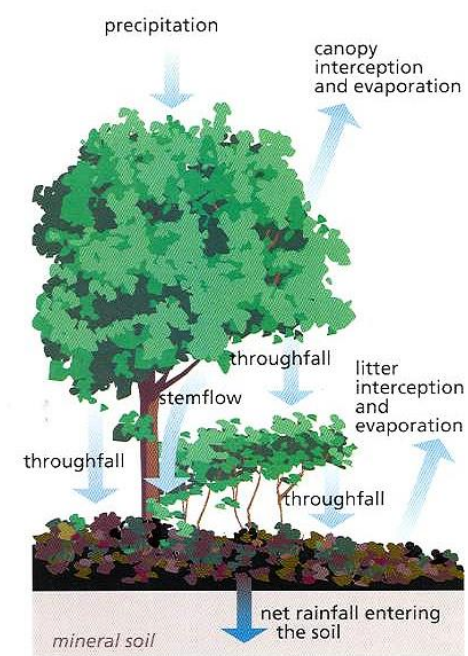
It's important to remember that altering one component of the water cycle affects all other elements of the cycle. Roads, buildings, parking lots and other impervious surfaces prevent rainfall from infiltrating into the soil and significantly increase runoff volume and flow.

As natural vegetation is replaced with impervious cover and natural drainage patterns are altered, the amount of evapotranspiration and infiltration decreases and stormwater runoff substantially increases.

Reduced evapotranspiration and infiltration from loss of vegetation

In a natural Virginia woodland or meadow, very little rainfall leaves the site as runoff. Runoff will occur from most wooded sites only after more than an inch of rain has fallen. In an undeveloped area, more than half of the annual amount of rainfall returns to the atmosphere through evapotranspiration.

Turf grass, which has commonly been used to replace natural vegetation, produces more runoff than natural open space and forestland, often because it is laid over compacted soil. Turf grass management can involve the application of large amounts of fertilizer and pesticides, which can be picked up by stormwater runoff and carried to local waterways.



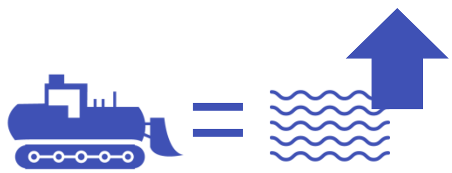
The benefits of tree canopy for stormwater management

NOTE:

Removing vegetation or changing the land type from woods and meadow to residential lawns reduces evapotranspiration and infiltration and increases stormwater runoff volume and flow.

Reduced infiltration from removal of topsoil and compaction of subsoil

When soil is disturbed by grading, stockpiling, and heavy equipment traffic, the soil becomes compacted, structure is lost, and the ability of water to flow in (infiltration) and through (percolation) the soil decreases. ***When this happens, the soil's ability to take in water (permeability) is substantially reduced and surface runoff increases***. Soil permeability is very important when selecting BMPs that rely on infiltration to remove pollutants or reduce runoff volumes.



Reduced groundwater recharge and reduced stream base flows

When precipitation runs off impervious surfaces rather than infiltrating and recharging the groundwater, it alters the hydrologic balance of the watershed. As a consequence, a stream's base flow is deprived of constant groundwater discharge, and the flow may diminish or even cease. Wetlands and headwaters reflect changes in groundwater levels most profoundly, and the reduced flow can stress or even eliminate the aquatic community.

During a drought, reduced stream base flow may also significantly affect the water quality in a stream. As the amount of water in the stream decreases, the oxygen content of the water often falls, affecting the fish and macroinvertebrates that live there. Reduced oxygen content can also lead to the release of pollutants previously bound up in bottom sediment.

Reduced infiltration from built or traditional drainage systems

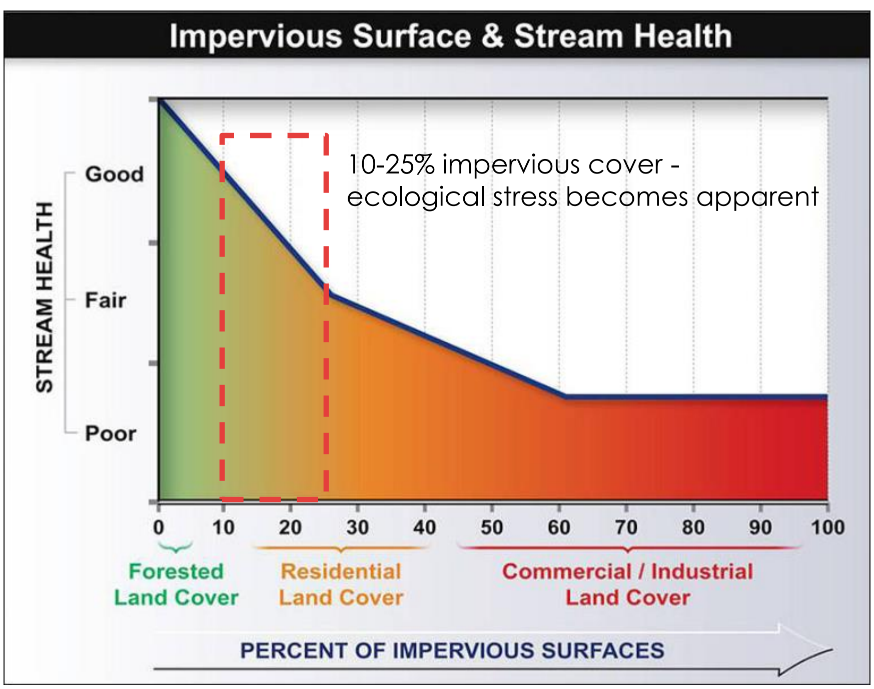
As stated earlier, depending on the magnitude of changes to the land surface, the total runoff volume can increase dramatically. This effect is further intensified by drainage systems such as gutters, storm sewers and smooth-lined channels that are designed to quickly carry runoff to rivers and streams.

Photo credit: ARC, 2001

Photo credit: Chesapeake Bay Stormwater Training Partnership

Declining watershed health from increased imperviousness

The amount of impervious cover in a watershed has been linked to the overall health or, conversely, degradation of that watershed. Research has shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes apparent (Schueler et al., 2009). Beyond 25 percent impervious cover, stream stability is reduced, habitat is lost, water quality is degraded, and biological diversity is diminished. This relationship is displayed in the graph below.

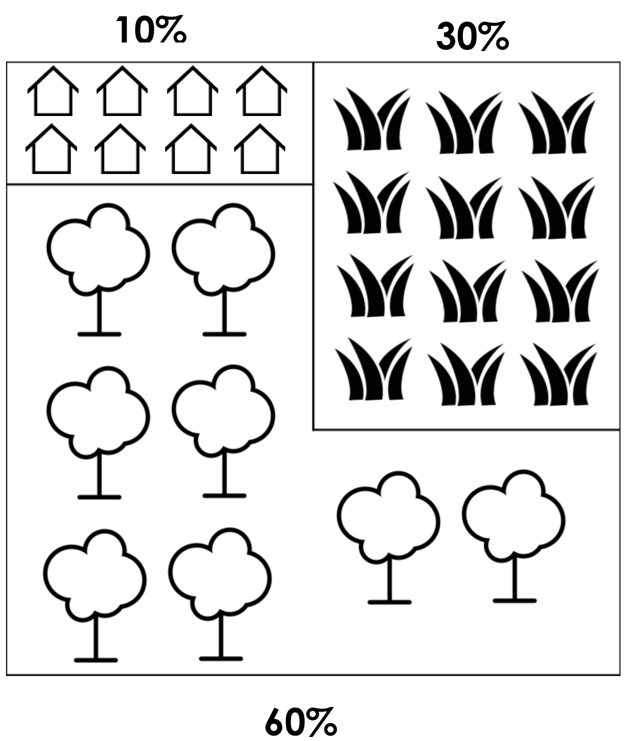


The Impervious Cover Model: How Imperviousness Impacts Stream Health
Chesapeake Bay Stormwater Training Partnership

LANDUSE AND THE PART II B WATER QUALITY CRITERIA

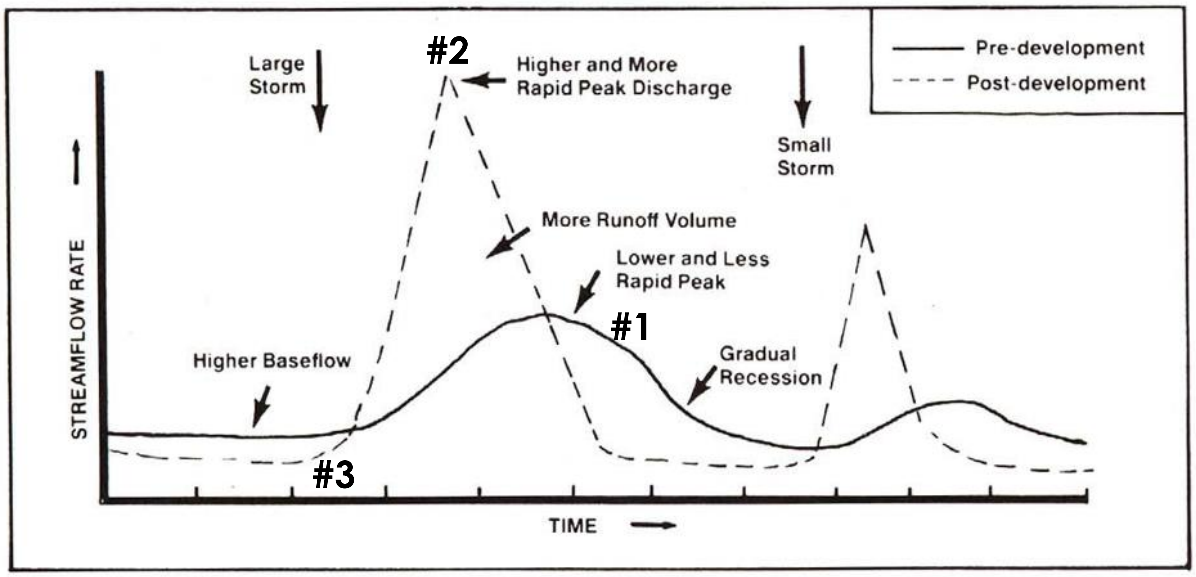
As mentioned in the overview, the Part II B water quality criteria establish a baseline of 0.41 lbs/acre/year of total phosphorus that can be allowed to leave a site through stormwater runoff at. The Virginia Runoff Reduction Method uses the Simple Method (modified to include impervious, managed turf and forest/open space) to calculate how much stormwater runoff and phosphorus is expected to leave a site ***based on landcover conditions***.

0.41 lbs./acre/year of total phosphorus is based on 10% impervious cover, 60% forest cover and 30% turf cover. 10% impervious cover was adopted from the Impervious Cover Model shown above as that's when ecologic stress becomes apparent. Managed turf is included in the calculation since increased runoff and pollutant levels are expected with this land cover type.



2c. Impact of Stormwater Runoff on Stream Channels and Flooding

The Part II B water quantity criteria address channel and flood protection because as stormwater runoff increases, there is a direct impact on stream channels and flooding. The hydrograph below shows how differently a stream responds to a storm and stormwater runoff in a pre- and post- development watershed.



Pre- and Post-Development Stormwater Runoff Hydrographs

1. Following a storm in a ***pre-development*** watershed, the peak discharge, or flow that occurs when the maximum flood state, or depth, in a stream is reached, gradually increases and gradually declines (curve is rounded).

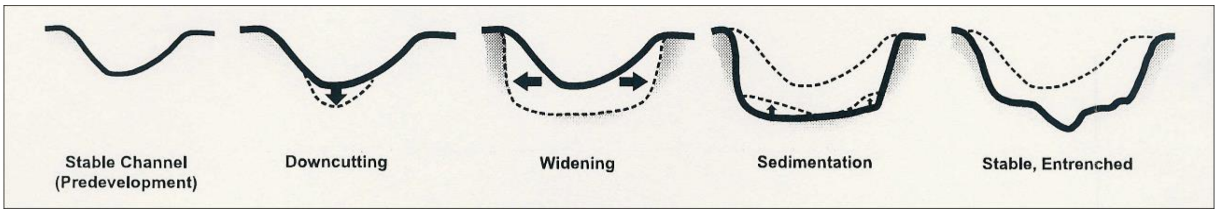
2. After a storm in a ***post-development*** watershed**,** the peak discharge can be two to five times higher than in a ***pre-development*** watershed. This characterization translates into the sharp peak and increased size of the post-development hydrograph.

   This happens in a ***post-development*** watershed because there is more impervious surface and less opportunity for evapotranspiration and infiltration.

3. It takes less time for runoff to travel over the impervious surface in a ***post-development*** watershed, so it takes less time for runoff to reach a stream (time of concentration). The energy of stream flows ranging from low to bankfull flows can most quickly alter a stream channel's physical shape and size.

The combination of greater volumes of runoff occurring more often and at higher flow rates, even in small storm events, can create:

- Altered stream flows that can affect water conditions and habitat for fish;
- Channel erosion, widening and downcutting that can degrade stream habitat and produce substantial increases in sediment loads from accelerated erosion; and
- Increased frequency of flooding and floodplain expansion.



Typical changes to a stream's physical characteristics due to watershed development

LANDUSE AND THE PART II B WATER QUANTITY CRITERIA

The Part II B water quantity criteria attempts to assure that runoff from a developed site will not cause damage to downstream properties or natural resources including not exceeding the capacity of a receiving stream channel for protection against channel erosion and flooding. This is done by maintaining the after-development runoff rate of flow and characteristics that replicate, as nearly as practicable, the existing pre-development runoff characteristics of the site. Alternatively, the criteria require improvements where channel erosion and/or flooding have already occurred.

2d. 15 Non-Proprietary Best Management Practices (BMPs)

Stormwater best management practices (BMPs) are used to reduce stormwater runoff and/or remove pollutants from stormwater runoff after construction has finished. The Regulations (9VAC25-870-65) allow for the use of the non-proprietary and proprietary BMPs listed on the Virginia Stormwater BMP Clearinghouse Website - http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html - to reduce the phosphorus load and runoff volume of stormwater in accordance with the Virginia Runoff Reduction Method. This section will provide an overview of the 15 non-proprietary BMPs.

#1 Rooftop (Impervious Area) Disconnection

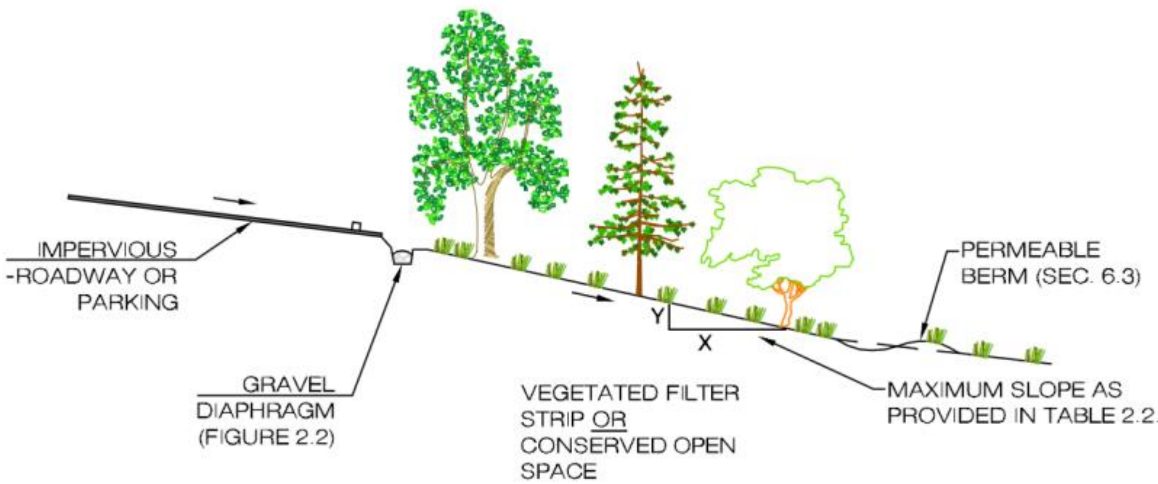
This strategy involves managing runoff close to its source by intercepting, infiltrating, filtering, treating, or reusing it as it moves from the impervious surface to the drainage system. Two kinds of disconnection are allowed:

1. Simple disconnection whereby rooftops and/or on-lot residential impervious surfaces are directed to pervious areas; and
2. Disconnection leading to an alternative runoff reduction practice(s) adjacent to the roof such as:
   - Soil compost amended filter path
   - Infiltration by micro-infiltration practice
   - Filtration by rain gardens or micro-bioretention
   - Storage and reuse with a cistern
   - Storage and release into a stormwater planter

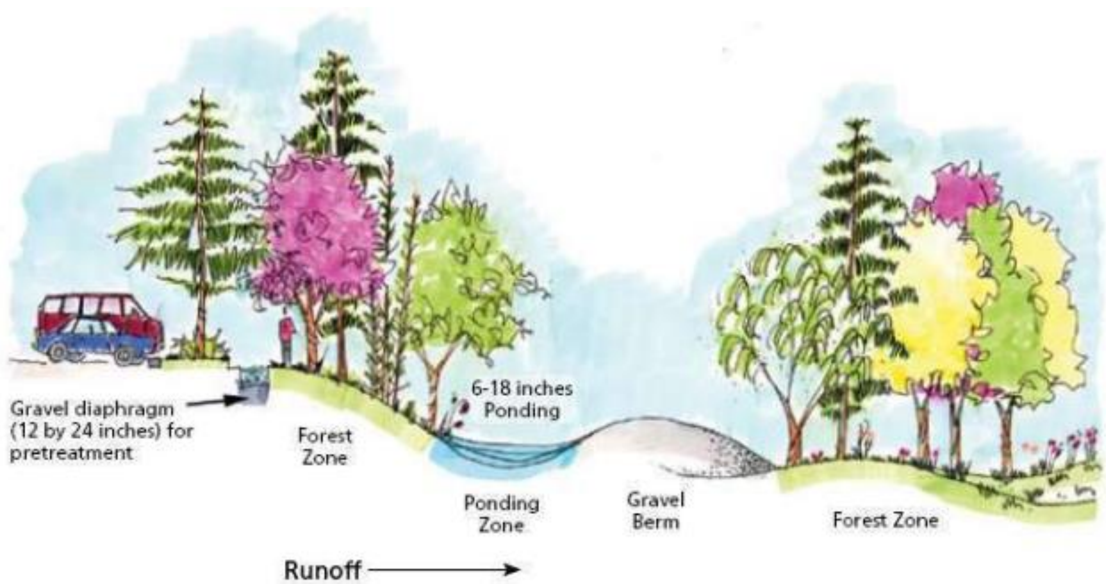
Rooftop disconnect

#2 Sheet Flow to a Vegetated Filter Strip or Conserved Open Space

Filter strips are vegetated areas that treat sheet flow delivered from adjacent impervious and managed turf areas by slowing runoff velocities and allowing sediment and attached pollutants to settle and/or be filtered by the vegetation. The two design variants are conserved open space and vegetated filter strips.



Sheet flow to vegetated filter strip



Sheet flow to open space

#3 Grass Channels

A grass channel is a stable, vegetated swale that is used as part of a stormwater conveyance system. Grass channels reduce stormwater runoff and pollutants by slowing the flow and providing the opportunity for infiltration.

Grass channels can be used to treat runoff from the managed turf areas of turf-intensive land uses, such as sports fields and golf courses, and drainage areas with combined impervious and turf cover (e.g., roads and yards).

Photo credit: Fairfax County

Photo credit: Montgomery County, MD

Photo credit: Maryland DOT

Photo credit: Stormwater Maintenance LLC

#4 Soil Compost Amendments

Soil compost amendments are applied to compacted soil after construction to restore its porosity. Soil amendments can reduce the generation of runoff from compacted urban lawns and may also be used to enhance the runoff reduction performance of downspout disconnections, grass channels, and filter strips.

Area being prepared for compost amendments
Photo credit: Center for Watershed Protection

Reseeded area with recently applied compost amendments

#5 Vegetated Roofs

Vegetated roofs are alternative roof surfaces that typically consist of waterproofing and drainage materials and an engineered growing media that is designed to support plant growth. Vegetated roofs capture and temporarily store stormwater runoff in the growing media before it is conveyed into the storm drain system. A portion of the captured stormwater evaporates or is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites.

There are two different types of vegetated roof systems:

1. *Intensive* vegetated roofs have a deep growing media layer that ranges from 6 inches to 4 feet thick, which is planted with a wide variety of plants, including trees; and

2. *Extensive* systems that typically have much shallower growing media (2 to 6 inches) and is planted with carefully selected drought tolerant vegetation.

Extensive green roof
Courtesy Chesapeake Bay Program

Intensive green roof
Photo credit: Chris Bruekner

#6 Rainwater Harvesting

Rainwater harvesting systems intercept, divert, store, and release rainfall for future use. The term rainwater harvesting is used in this specification, but it is also known as a cistern or rainwater harvesting system. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing (e.g. car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), and fire suppression (sprinkler) systems.

In many instances, rainwater harvesting can be combined with a secondary (down-gradient) runoff reduction practice to enhance runoff volume reduction rates and/or provide treatment of overflow from the rainwater harvesting system.

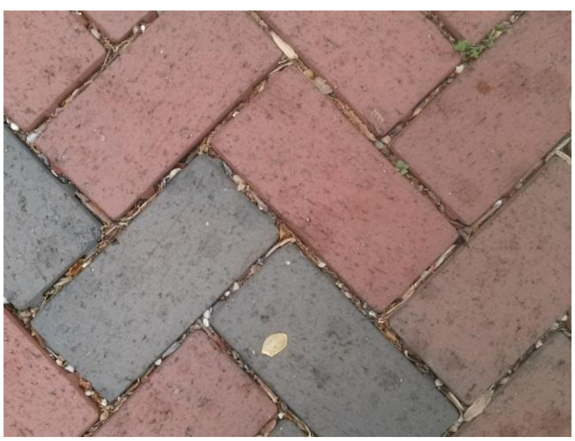
Courtesy Chesapeake Bay Program

#7 Permeable Pavement

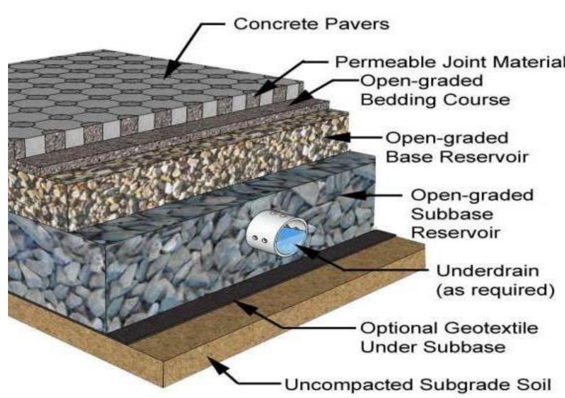
Permeable pavement is an alternative to asphalt or concrete that allows stormwater to filter through openings in the surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including **porous concrete**, **pervious asphalt,** and **permeable interlocking concrete pavers**. While the specific design may vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom.

Porous concrete

Pervious asphalt
Photo credit: NEMO UConn



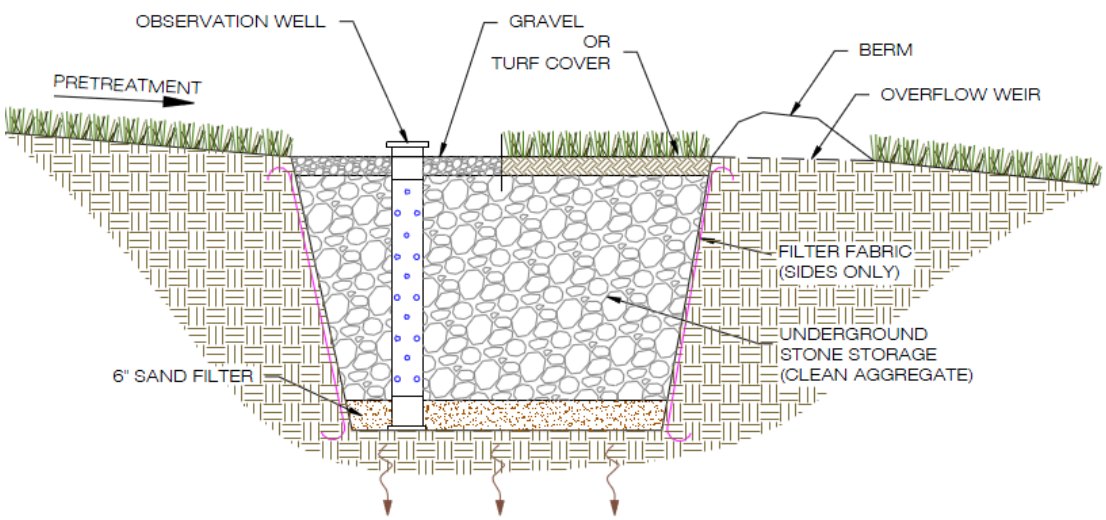
Permeable interlocking concrete pavers



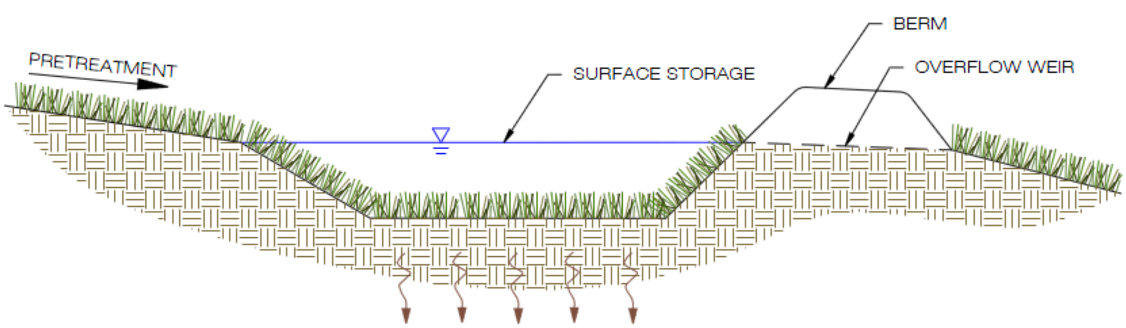
Cross section of concrete pavers

#8 Infiltration

Infiltration practices use temporary surface or underground storage to allow incoming stormwater runoff to go into underlying soils. Runoff first passes through multiple pretreatment mechanisms to trap sediment and organic matter before it reaches the practice. As the stormwater penetrates the underlying soil, chemical and physical adsorption processes remove pollutants. Infiltration practices have the greatest runoff reduction capability of any stormwater practice and are suitable for use in residential and other urban areas where ***measured*** soil permeability rates exceed 1/2 inch per hour.



Infiltration trench



Infiltration basin

#9 Bioretention Basins

A bioretention facility is a depressed area that uses a custom soil mix and plants to reduce stormwater runoff and filter pollutants – much like a forested ecosystem. The primary component of a bioretention practice is the filter bed, which has a mixture of sand, soil, and organic material as the filtering media with a surface mulch layer.

During storms, runoff temporarily ponds six to 12 inches above the mulch layer and then rapidly filters through the bed. Normally, the filtered runoff is collected in an underdrain and returned to the storm drain system. The underdrain consists of a perforated pipe in a gravel layer installed along the bottom of the filter bed. Bioretention facilities can be used in a variety of locations including:

- Parking lot islands
- Parking lot edges
- Curb extensions
- Courtyards
- Residential lots

Urban bioretention
Photo credit: VA DGS

Micro-bioretention or rain garden
Photo credit: Chesapeake Stormwater Network

Bioretention basin
Courtesy Chesapeake Bay Program

#10 Dry Swales

Dry swales are essentially bioretention cells that are shallower, configured as linear channels, and covered with turf or other surface material (other than mulch and ornamental plants). They are a soil filter system that temporarily stores and then filters the desired treatment volume. Dry swales rely on a pre-mixed soil media filter below the channel that is similar to that used for bioretention. If soils are extremely permeable, runoff infiltrates into underlying soils. In most cases, however, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream.

Dry swales may appear as simple grass channels with the same shape and turf cover, while others may have more elaborate landscaping. Swales can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

Dry swale
Photo credit: Montgomery County Planning District Commission

#11 Wet Swales

Wet swales can provide runoff filtering and treatment within the conveyance system and are a cross between a wetland and a swale. These linear wetland cells often intercept shallow groundwater to maintain a wetland plant community. The saturated soil and wetland vegetation provide an ideal environment for gravitational settling, biological uptake, and microbial activity. On-line or off-line cells are formed within the channel to create saturated soil or shallow standing water conditions (typically less than six inches deep).

Wet swale

#12 Filtering Practices

Stormwater filters are a useful practice to treat stormwater runoff from small, highly impervious sites. Stormwater filters capture, temporarily store, and treat stormwater runoff by passing it through an engineered filter media, collecting the filtered water in an underdrain, and then returning it back to the storm drainage system. The filter consists of two chambers. The first chamber is devoted to settling, and the second serves as a filter bed consisting of sand or organic filter media.

Underground sand filter
Photo credit: CWP

Perimeter sand filter
Photo credit: CWP

Surface sand filter with turf cover
Photo credit: CWP

Surface sand filter
Photo credit: CWP

#13 Constructed Wetlands

Constructed wetlands, sometimes called stormwater wetlands, are shallow depressions that receive stormwater inputs for water quality treatment. Wetlands are typically less than one-foot deep and possess variable microtopography to promote dense and diverse wetland cover.

Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to occur. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity. Constructed wetlands are the final element in the roof-to-stream runoff reduction sequence. They should only be considered for use after all other upland runoff reduction opportunities have been exhausted and there is still a remaining water quality or channel protection volume to manage.

Constructed wetland
Photo credit: Seuss

#14 Wet Pond

Wet ponds consist of a permanent pool of standing water that promotes a better environment for gravitational settling, biological uptake, and microbial activity. Runoff from each new storm enters the pond and partially displaces water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a residence time that ranges from many days to several weeks, which allows numerous pollutant removal mechanisms to operate. Wet ponds can also provide extended detention above the permanent pool to help meet channel protection requirements.

Wet pond

#15 Extended Detention Pond

An extended detention pond relies on 12 to 24 hour detention of stormwater runoff after each rain event. An under-sized outlet structure restricts stormwater flow so it backs up and is stored within the basin. The temporary ponding enables particulate pollutants to settle out and reduces the maximum peak discharge to the downstream channel, thereby reducing the effective shear stress on banks of the receiving stream.

Extended detention pond

2e. Summary

In summary, the Part II B ***water quality*** technical criteria establish a baseline load of total phosphorus that can be allowed to leave a site through stormwater runoff. The goal of the criteria is to protect waterways from the adverse effects of increased pollutants.

The goal of the Part II B ***water quantity*** criteria is to assure that runoff from a developed site does not impact downstream properties or natural resources by restricting the peak flow and managing the volume. It also seeks to ensure that increased runoff does not exceed the capacity of a receiving stream channel in order to protect against channel erosion and flooding, or requires improvements where erosion and/or flooding have already occurred.

The criteria can be accomplished by reducing the volume of stormwater runoff that leaves a site through the use of Environmental Site Design and DEQ approved BMPs rather than just conventional stormwater facilities for water quantity compliance.